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The Potential Role of the IUGS Global Heritage Stone Initiative

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Article abstract

Natural stone has been used for millennia in many historically and culturally important structures. It inevitably undergoes weathering from natural processes and damage from human activities. Deterioration affects both ornamental features and main structural members of constructions, ultimately requiring repair and maintenance, or causing loss of the structure altogether. Stone similar to the original should generally be used for repairs, but if that is impossible, a closely similar material is required. Use of inappropriate stone or treatment with incompatible mortars can be aesthetically unsightly or have structurally and financially damaging consequences. Such use typically arises because of a lack of information and awareness among commissioners and specifiers of works, along with budget constraints leading to selection of cheaper alternatives. Even some World Heritage Sites have suffered. Selected examples from Western Europe illustrate these problems. The Global Heritage Stone initiative has been launched to improve recognition of the internationally most important heritage stones, promote their proper use in construction, maintenance and repair, and to stress the need to safeguard important stone resources for future use.

SERIES

Heritage Stone 1. Repair and Maintenance of Natural Stone in Historical Structures: The Potential Role of the IUGS Global Heritage Stone Initiative*

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SUMMARY

Natural stone has been used for millennia in many historically and culturally important structures. It inevitably undergoes weathering from natural processes and damage from human activities. Deterioration affects both ornamental features and main structural members of constructions, ultimately requiring repair and maintenance, or causing loss of the structure altogether. Stone similar to the original should generally be used for repairs, but if that is impossible, a closely similar material is required. Use of inappropriate stone or treatment with incompatible mortars can be aesthetically unsightly or have structurally and financially damaging consequences. Such use typically arises because of a lack of information and awareness among commissioners and specifiers of works, along with budget constraints leading to selection of cheaper alternatives. Even some World Heritage Sites have suffered. Selected examples from Western Europe illustrate these problems. The Global Heritage Stone initiative has been launched to improve recognition of the internationally most important heritage stones, promote their proper use in construction, maintenance and repair, and to stress the need to safeguard important stone resources for future use.

RÉSUMÉ

La pierre naturelle a été utilisée depuis des millénaires dans de nombreuses structures importantes historiquement et culturellement. Inévitablement cette pierre s'altère sous l'effet de processus naturels et de dommages causés par les activités humaines. Cette détérioration affecte aussi bien les éléments ornementaux que les principaux éléments structuraux des constructions, ce qui, éventuellement nécessite réparation et entretien, ou alors peut entraîner la perte de la structure. Une pierre semblable à l'originale doit généralement être utilisée pour des réparations, ou alors un matériau très similaire est requis. L'utilisation d'une pierre inappropriée ou un traitement avec des mortiers incompatibles peut être esthétiquement disgracieux ou avoir des conséquences structurellement et financièrement préjudiciables. Cette utilisation erronée est typiquement le résultat d'un manque d'information et de sensibilisation des commissaires et des rédacteurs du cahier des charges, ainsi que de contraintes budgétaires conduisant au choix d'options moins coûteuses. Et même, certains sites du patrimoine mondial en ont souffert. Des exemples choisis de l'Europe de l'ouest illustrent ces problèmes. L'initiative du patrimoine mondial de la pierre de taille lancée pour améliorer la conscience à l'échelle internationale des principales pierres du patrimoine, promouvoir leur utilisation correcte dans la construction, leur entretien et leur réparation, et souligner la nécessité de préserver les ressources importantes en pierre pour les besoins à venir.

Traduit par le Traducteur

*This article is part of a set of papers dedicated to the memory of Anders Wikström published in Geoscience Canada Special Issue: Heritage Stone; a new series that is guest edited by Dolores Pereira and Brian R. Pratt.

Figure 1. Examples of war damage: a) Cathedral in Ciudad Rodrigo (Salamanca, Spain) showing cannon ball impacts from the siege during the Peninsular War between French and Anglo-Portuguese and Spanish forces in the early 19th century. b) and c) parts of the façade of the Victoria and Albert Museum in London showing damage to the Portland Stone from casing fragments when bombs were dropped nearby. The damage was deliberately left unaltered when the façade was cleaned and repaired in 1985.

INTRODUCTION

Natural stone has been used in construction for thousands of years but is affected by the same processes of weathering by water, wind, frost, heating and biological activity as bedrock exposures of the same rocks. Inevitable progressive deterioration reflects the nature and properties of the stone, the passage of time and the ambient conditions, both natural and anthropogenic, to which it is exposed. Causes of deterioration of stone are varied, and include cracking and deformation, detachment, loss of material through erosion and mechanical damage, effects of discolouration and surface deposits, and biological colonization (e.g. algae, bacteria) (ICOMOS-ISCS 2008). Many stone-built structures are in urban areas. Particularly since large-scale industrialization, these structures have been exposed to aggressive attack by pollutants, accelerating the rate of decay. Because of early industrialization and large numbers of historically important structures, western Europe is an instructive area for observing causes of decay and possible approaches to reducing future damage to the historical, cultural and architectural heritage.

Article 4 of the UNESCO 'Convention concerning the protection of the World cultural and natural heritage' states that "*Each State Party to this Convention recognizes the duty of ensuring the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage*" (whc.unesco.org/en/conventiontext). This can help to protect national heritage and can contribute to income from tourism. Governments address this obligation in different ways depending on their national priorities and provisions for protecting heritage. However, positive efforts can be undermined by political instability and loss of control. Wars and vandalism have endangered historical areas and sites for centuries, causing damage or, in some cases, complete destruction (Fig. 1). Recent and current political instability in some places, including some UNESCO World Heritage sites, is a matter for continuing concern but can only be solved by conflict resolution.

More widely, anthropogenic deterioration, whether conscious or unconscious, or caused by climate and weather (http://whc.unesco.org/en/danger/), can be addressed by good practices for repair and maintenance (Pereira et al. 2015a).

DETERIORATION, MAINTENANCE AND REPAIR

Inappropriate maintenance and repair, development projects, inadequate management systems, and insufficient legal protection can threaten either important structures or groups of individually less important buildings that, together, constitute significant conservation areas. The rate of deterioration of stone depends on the initial quality and can progress to a condition in which only replacement can secure the future of the building or monument.

Intervention at the right time can preserve, or extend the life of, the cultural heritage but technically and aesthetically appropriate materials must be selected to retain both visual appearance and the structural integrity of constructions. It is recommended that original types of stone be used for maintenance and repair, but that may be impossible if resources have been exhausted, built-over, or have otherwise become inaccessible. In that case, detailed and readily accessible technical information is needed to identify the most appropriate alternatives.

SOME EXAMPLES FROM EUROPE

Inappropriate actions in the repair and maintenance of buildings occur widely, even in parts of UNESCO World Heritage cities and sites. Some examples of problems in these and other locations in western Europe serve to illustrate the salient issues.

Palace of Westminster, London, UK

Original selection of stone was not always good, even in the case of some prestigious buildings. An example is the Palace of Westminster (often referred to as the Houses of Parliament) in London, UK, which has World Heritage status (Fig. 2). The original medieval buildings were largely destroyed by fire in 1837. A replacement was commissioned in the then popular Gothic Revival style and was completed in stages between 1847 and 1852 (www.parliament.uk/about/living-heritage/building/palace/architecture/palacestructure/the-stonework). The stone selected for the new building was *Anston Stone* (Cadeby Formation, late Permian), a dolomitic limestone from Nottinghamshire (Anonymous 2012a). A variety called 'Mansfield White' was selected because it could be easily carved and was available at a favourable price. However, it performed badly from the outset because of rapid weathering exacerbated by acidic rainfall and fog resulting from the predominant use of coal as a fuel in London until the mid-20th century and, subsequently, pollutants mainly from road traffic. By the 1930s it was necessary to begin replacing the Anston Stone with Clipsham Stone (Middle Jurassic), a pale ooidal to bioclastic limestone similar in colour to Mansfield White but with different physical properties (Anonymous 2012b). After suffering bomb damage in the 1940s that program was completed in the 1950s and thus most of the present façade is in Clipsham Stone. But, by the 1960s, damage was again evident, leading to further works from 1984 to 1991. However, in 2012 it was again necessary to begin extensive repair work, which is likely to last for many years but at a cost of several billion £GB. Although the Anston Stone had proved to be inadequate, significant amounts still remain in the structure. But as the Clipsham Stone has also deteriorated badly, this raises the issue of whether newly quarried Clipsham Stone should be used for partial compatibility, or whether a more durable stone might replace it even though that could affect the future performance of older parts of the structure. This illustrates the need to select good stone at the outset, taking into account the environmental conditions that it will be exposed to and the dilemma that can face the repairer after an alternative replacement stone has been used.

Figure 2. The Palace of Westminster showing pale-coloured Clipsham Stone from recent repairs, contrasting with Clipsham Stone from previous repairs and Anston Stone.

Clerecía Church, Salamanca, Spain

Originally known as the Royal College of the Company of Jesus, construction of the Clerecía Church began during the 17th century in Baroque style, using Salamanca sandstone in the lower part and Villamayor sandstone in the upper part of the building. This church is part of the Salamanca World Heritage site. The lower part deteriorated unevenly as a result of water adsorption through the more porous parts of the stone, as well as several inappropriate actions such as covering some parts with mortar and replacing blocks in the frontage of the church. Limited understanding of natural stone led the architects in charge of the restoration of the Clerecía Church to use various igneous rocks to replace the sandstone (Fig. 3). The result is a poor aesthetic effect that could have been easily avoided by awareness of available local material (Pereira and Cooper 2014).

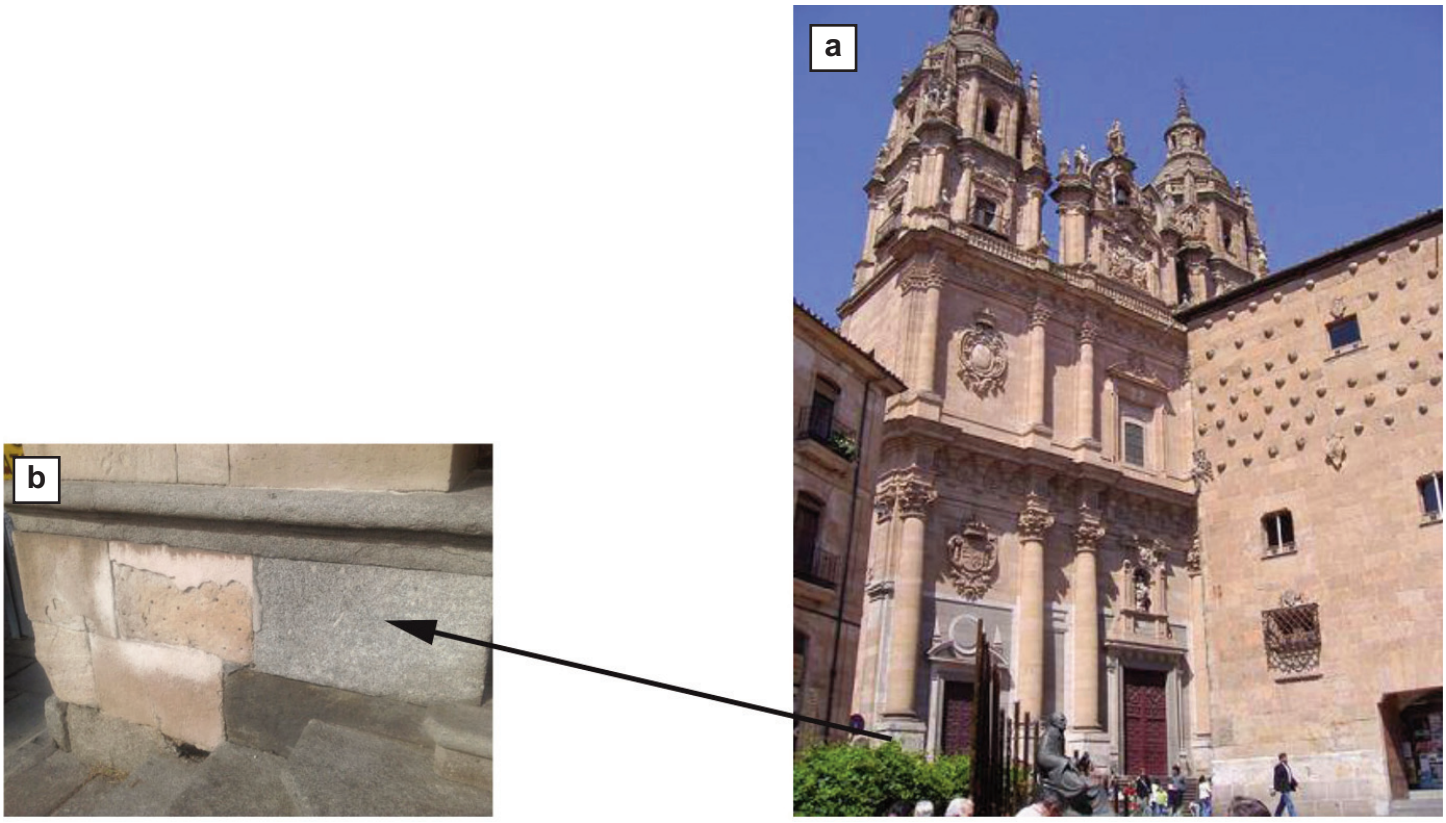

Figure 3. a) Clerecía Church, Salamanca; b) replacement of sedimentary stone (Villamayor sandstone) by various igneous rocks.

British Museum, London, UK

The British Museum was founded in 1753 as the world's first national public museum. The present building on the site was constructed in stages between the 1820s and 1850s using granite for the base courses and *Portland Stone* (Tithonian, Upper Jurassic) for the main body of the structure (http://www.britishmuseum.org/about_us/the_museums_story). In 2000, an internal courtyard was roofed over to form the Queen Elizabeth II Great Court, expanding visitor space by some 40%. The original Ionic portico of the courtyard had been demolished in the late 19th century. It was to be replaced (Fig. 4a) and the specification stated that the work should use 'stone from Portland.' In the event, Middle Jurassic stone imported from France (via Portland) was used, causing a major controversy in which some people considered that the stone was inappropriate while others praised the major architectural achievement (www.theguardian.com/the observer/2000/nov/12/2). The colour and texture do not match and, since this part of the building is sheltered from weathering, the contrast is unlikely to decrease over time. This illustrates the importance of precise specification of stone but also raises the question of whether some changes should be allowed for architectural reasons.

Lincoln Cathedral, Lincolnshire, UK

Lincoln Cathedral is regarded as one of the most important historic buildings in England. Building commenced in 1088 and continued in stages for several hundred years, and it was reputedly the tallest building in the world between 1311 and 1549 (Pevsner 1989). Like many other medieval cathedrals, it is under a continuous process of maintenance and repair. Current repair and maintenance work employs appropriate stone but the building shows evidence of 19th and early 20th century interior work that is aesthetically unpleasing. Parts of the interior walling were originally built with red sandstone (Triassic) but some repairs were made with white limestone (Lincolnshire Limestone; Bajocian, Middle Jurassic) (Ashton 1980), of a type used extensively elsewhere in the cathedral. This resulted in an irregular patchwork of contrasting colours (Fig. 4b) that some consider undesirable.

Chipping Norton, Oxfordshire, UK

Many buildings in the town of Chipping Norton date from the 18th century and were constructed mainly with *Hornton Stone* (bioclastic ferruginous limestone; Pleinsbachian–Toarcian, Lower Jurassic). This stone is susceptible to spalling. Chipping Norton Limestone (oolitic limestone; Bajocian, Middle Jurassic) (Horton and Edmonds 1987; Radley 2003, 2009) was used for detailing around windows in the structure illustrated in Figure 4c, providing a pleasing contrast. That colour pattern was disrupted by later repairs that used Middle Jurassic limestone in place of some of the darker Hornton Stone (Fig. 4c); the result is not likely to become visually compatible even after a period of weathering.

Salamanca, Turin and Oxford

Salamanca (Spain) was recognized as an UNESCO world heritage site in 1988, mainly because of the homogenous construction of the old town using local natural stone and the optimum state of conservation. Buildings in central Salamanca were constructed using Villamayor sandstone (García Talegón et al. 2015) and Salamanca sandstone (Nespereira et al. 2010;

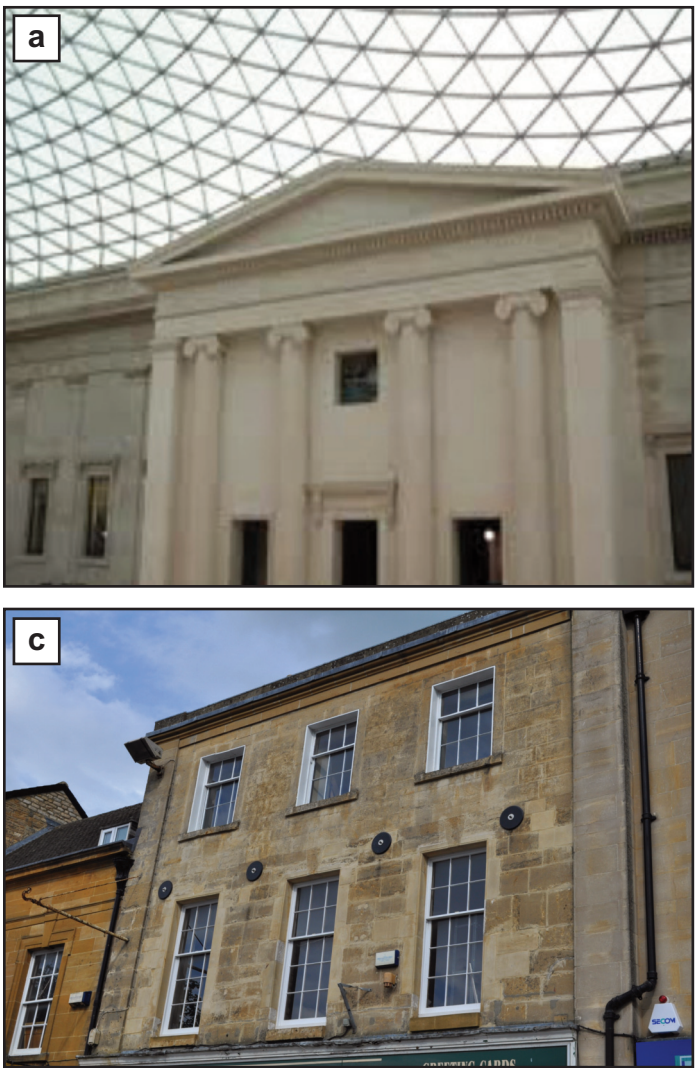

Figure 4. Examples of controversial or poor practices of stone usage. a) Queen Elizabeth II Courtyard, British Museum, London; b) contrasting replacement of stone in the interior of the Lincoln Cathedral, and c) replacement with stone of a different colour disrupting the original colour pattern in the exterior of the cathedral, Chipping Norton, Oxfordshire.

Pereira and Cooper 2014) for most of the structures. However, granite was used in the lower parts of the buildings after it was realized that the sandstones were not resistent to water absorption and became weak under critical conditions (Pereira et al. 2015a). Humidity and contamination have had negative influences on the sandstones, leaving some buildings in a very poor state. Mortar was used to disguise the deterioration, a common mistake because it can react chemically with minerals in the stone, especially where the stone has a high water absorption coefficient. The reactions cause accelerating deterioration as the mortar continues reacting with the sandstone matrix and cement, and can lead to complete destruction of the stone (Fig. 5a). Similar circumstances occurred in, for example, Turin (Italy), where attempts were made to obscure deterioration of the *Floresto Marble* by covering it with mortar (Fig. 5b) and Oxford (UK), where mortar has been used to 'repair' limestone (Fig. 5c). Granites can also be affected adversely by inappropriate coverings (Fig. 6); although the result is less dramatic than in the case of sandstone and limestone, at least in the short term; it is nevertheless aesthetically undesirable.

Hampstead, London, UK

An extreme example of inappropriate repair, presumably because it was undertaken at the lowest possible cost, can be observed at the front of a bank in Hampstead, London. The façade was constructed with *Doulting Stone* from Avon (crinoidal biosparite; Bajocian, Middle Jurassic), which contains numerous large *Thalassinoides* burrows (Richardson 1915). The infilled burrows are more porous than the body of the rock, and weather more quickly. During 'repair,' the hollows associated with these burrows were simply cemented over but some red bricks were also used to replace seriously weathered stone blocks, producing a poor visual result (Fig. 7). While this is a minor building, these repairs detract from the late 19th century terrace of which it is a part.

THE GLOBAL HERITAGE STONE RESOURCE AND GLOBAL HERITAGE STONE PROVINCE CONCEPTS

Poor practice can, therefore, involve poor initial selection of stone. But inappropriate replacement of stone is widespread, often because of a lack of technical information and understanding among some architects, contract specifiers of stone, and commissioning bodies such as local government and private companies. Even if technical information is available, less desirable but cheaper stone or inappropriate use of mortar or cement, may be selected to fit project budgets, without consideration of the longer term consequences in cost and further damage. Materials that are incompatible with the original fabric

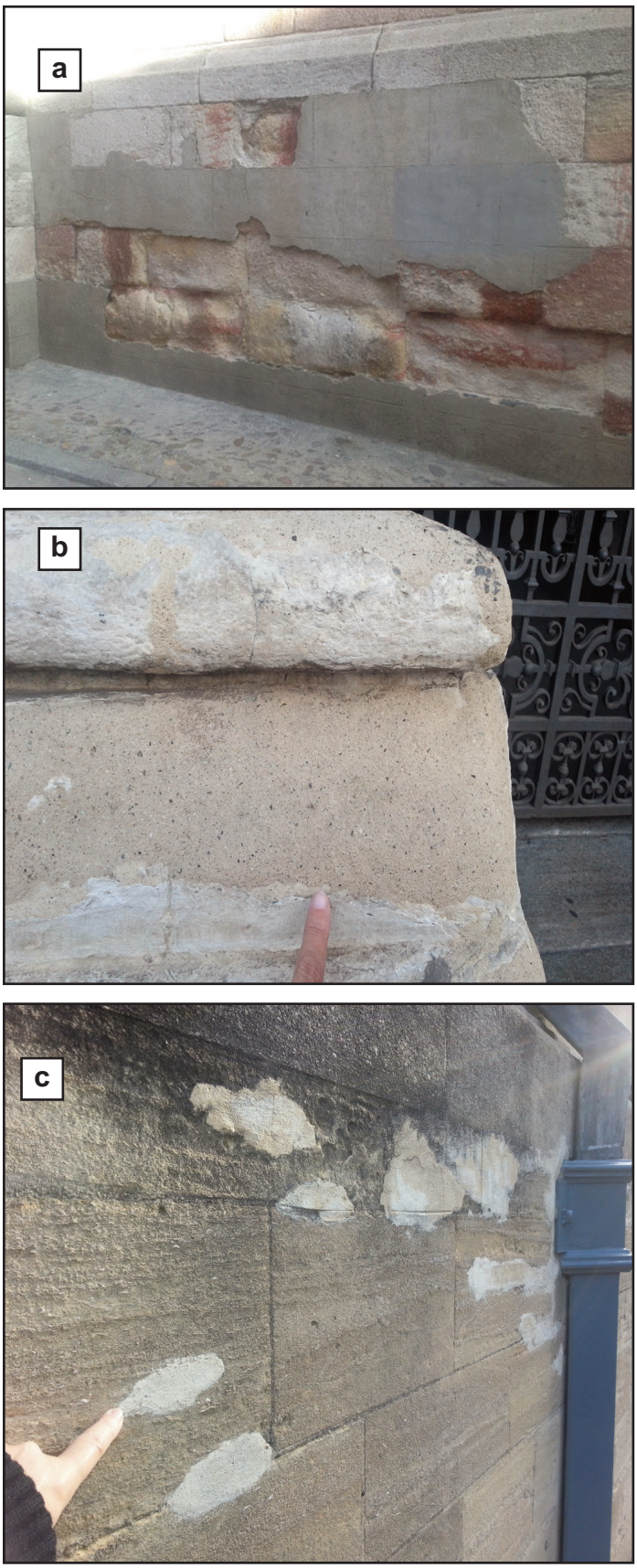

Figure 5. Inappropriate use of mortar in repairs. a) Use of mortar on an opal-cemented conglomerate (Salamanca sandstone) in an historic building in Salamanca; b) use of mortar on limestone (Floresto Marble) in an historic building in Turin; c) use of mortar on limestone in a building in Oxford.

Figure 6. The Roman Wall around the World Heritage City of Cáceres, Spain, and use of mortar that contrasts markedly with the original colour of the granite forming the wall.

of the structure can either cause further or accelerated deterioration of the original stone and can be visually and aesthetically undesirable.

There is a need, therefore, to raise awareness and understanding of the importance of good practices for the maintenance and repair of the natural stone heritage. The Global Heritage Stone Resource (GHSR) and Global Heritage Stone Province (GHSP) concepts were developed by the Heritage Stone Task Group (a working group within the International Union of Geological Sciences) at the 33rd International Geological Congress of 2008 in Oslo as a step towards improving the situation. The initiative aims to establish new, formal, international geological designations for important types of natural stone that have been widely used and/or have widespread cultural and architectural recognition (GHSR), and of areas (GHSP) that contain more than one type of stone that would qualify for GHSR status (Cooper et al. 2013). It also aims to develop internationally accepted standard approaches to the reporting of technical and aesthetic characteristics of natural stones used for repair and maintenance of historic buildings, monuments and structures as well as for new construction. Formalization should help to increase awareness of the potential uses of various GHSR and provide important information for those engaged in using stone for repair and maintenance. Stones that have been used in heritage construction and sculptural masterpieces, as well as in utilitarian (yet culturally important) applications are obvious candidates for GHSR status. To achieve these aims, the GHSR and GHSP designations must

Figure 7. Part of the façade of a bank in Hampstead, London, showing inappropriate use of cement and brick in repairs to Doulting Stone.

be promoted and adopted by international and national authorities (Cooper et al. 2013).

Adoption of the GHSR and GHSP designations can have long-term benefits. Formalized reporting of the characteristics of natural stone for professional purposes, whether geological or in contractual specification of types of stone to be used in repair and maintenance, will help ensure that appropriate materials are used. Within the European Union there are three legally binding schemes in the agricultural sector: the protected designation of origin (PDO); protected geographical indication (PGI); and traditional speciality guaranteed (TSG), particularly for regionally important foodstuffs and wines (ec.europa.eu/agriculture/quality/schemes/index_en.htm). The aim is to prevent other areas from marketing produce purporting to be from the original place of production. The possibility of a similar approach to designation of stone has been raised to prevent imported materials from being substituted improperly for original types of stone.

The heritage stone designation can, if properly disseminated, create increased awareness of available and appropriate natural stone among professional workers in geology, engineering, architectural and artistic work, in stone/building conservation, and the general public. In addition, the designation can enhance international cooperation for research on, and documentation of, natural stone resources. This has already been demonstrated by the enthusiastic response and numerous contributions to specific sessions at international meetings and publications dedicated to this topic (e.g. Pereira et al. 2015a, b). Success of the GHSR and GHSP designations should also help to encourage proper management of natural stone resources, including future protection of important dimension stone resources from sterilization by other forms of development (Cooper et al. 2013; Pereira and González-Neila in press).

The Heritage Stone Task Group has formally considered whether Portland Stone (Hughes et al. 2013) from the UK should be the first Heritage Stone Resource to be designated. A decision is expected soon. The Group has promoted numerous papers describing selected natural stones from many parts of the world that might become candidate stones for formal designation (e.g. Pereira and Cooper 2013; García-Talegón et al. 2015; Pereira et al. 2015a) in the coming years. But it remains to be seen how many will be formally proposed and whether the designation will be fully recognized by international and national bodies.

CONCLUSIONS

As far as possible, natural stone similar to the original source should be used in repair and replacement so that adverse consequences for the historic and architectural heritage can be minimized. If that is impossible, a closely similar material is required. Use of inappropriate stone or treatment with incompatible mortars can have structurally and financially deleterious consequences, and can be aesthetically unsightly. Inappropriate use usually arises from a lack of information and awareness amongst commissioners and specifiers of works, and from budget constraints leading to selection of cheaper alternatives. Initial selection of suitable stone is important but inappropriate attempts at repair have exacerbated problems even in some World Heritage Sites. Selected examples from western Europe illustrate inappropriate use of mortar and replacement of stone. The Global Heritage Stone initiative has been launched to encourage standard reporting of technical data on, and to improve recognition of, the internationally most important heritage stones, as well as to

promote their proper use in construction, maintenance and repair, and to stress the need to safeguard important stone resources for future use.

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